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(54) **INTEGRATED BATTERY SERVICE SYSTEM**

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(52) **U.S. Cl.** **702/63**

(58) **Field of Classification Search** 702/63, 702/64, 60, 182–185, 188

See application file for complete search history.

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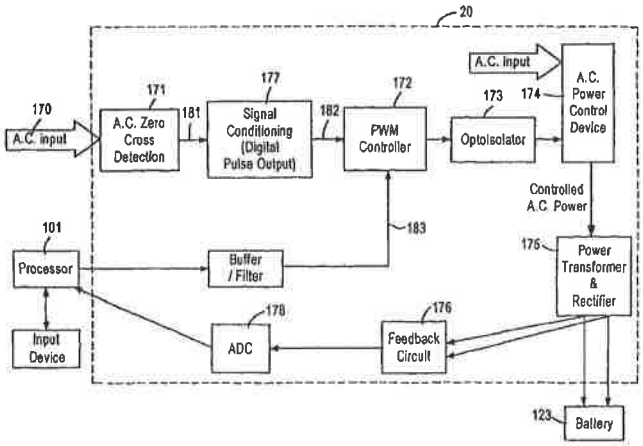
(57) **ABSTRACT**

An integrated battery service system performs a plurality of services related to a battery, such as battery testing, battery charging, and the like. In addition, the integrated service system provides services to devices/components that are coupled to the battery, such as starters, alternators, etc. The integrated battery service system allows a user to abort a service and then resume the process from where the process was aborted. When conducting a service, the integrated battery service system determines a noise level caused by devices/components coupled to the battery. The integrated battery service system includes connectors configured to couple to a battery for receiving input signals, a processor coupled to the connectors, and a memory device coupled to the processor for storing control codes and operation history. The control codes, when executed by the processor, control the system to selectively abort a service in response to a user input. Since the memory stores operation histories, the processor may access the memory to retrieve data related to the aborted service and parameters obtained during the service before the process was aborted. The system reinstates the aborted service in response to another user input.

72 Claims, 9 Drawing Sheets



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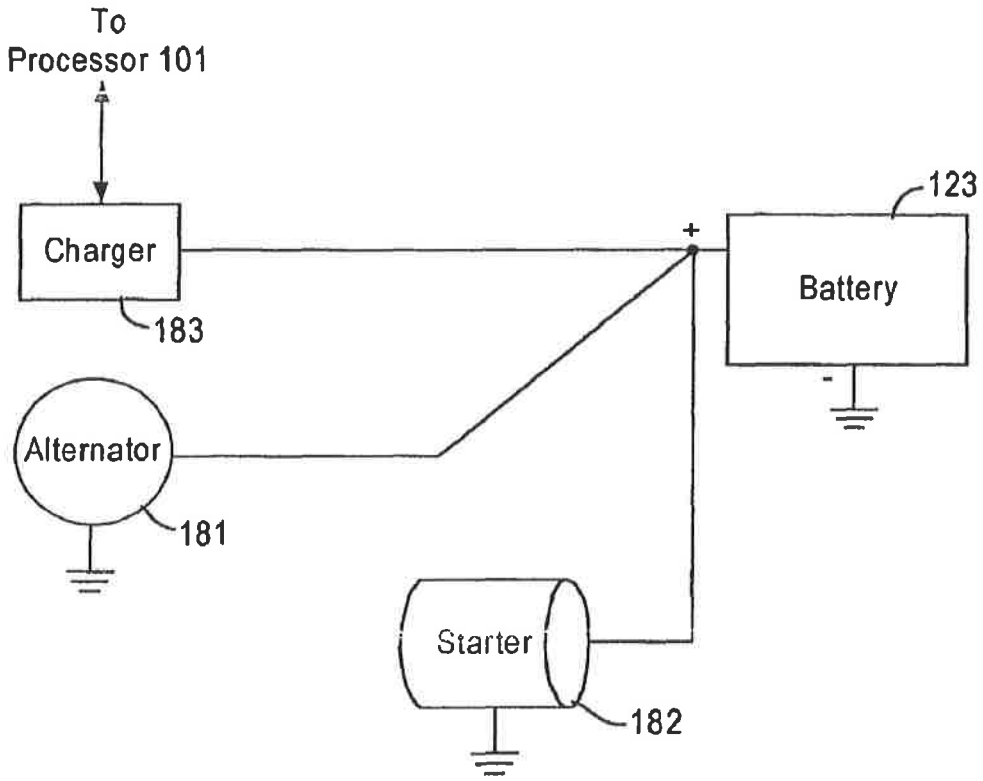
To
Processor 101
Charger
183
Alternator
181
Starter
182
Battery
123
+
-

FIG. 1A

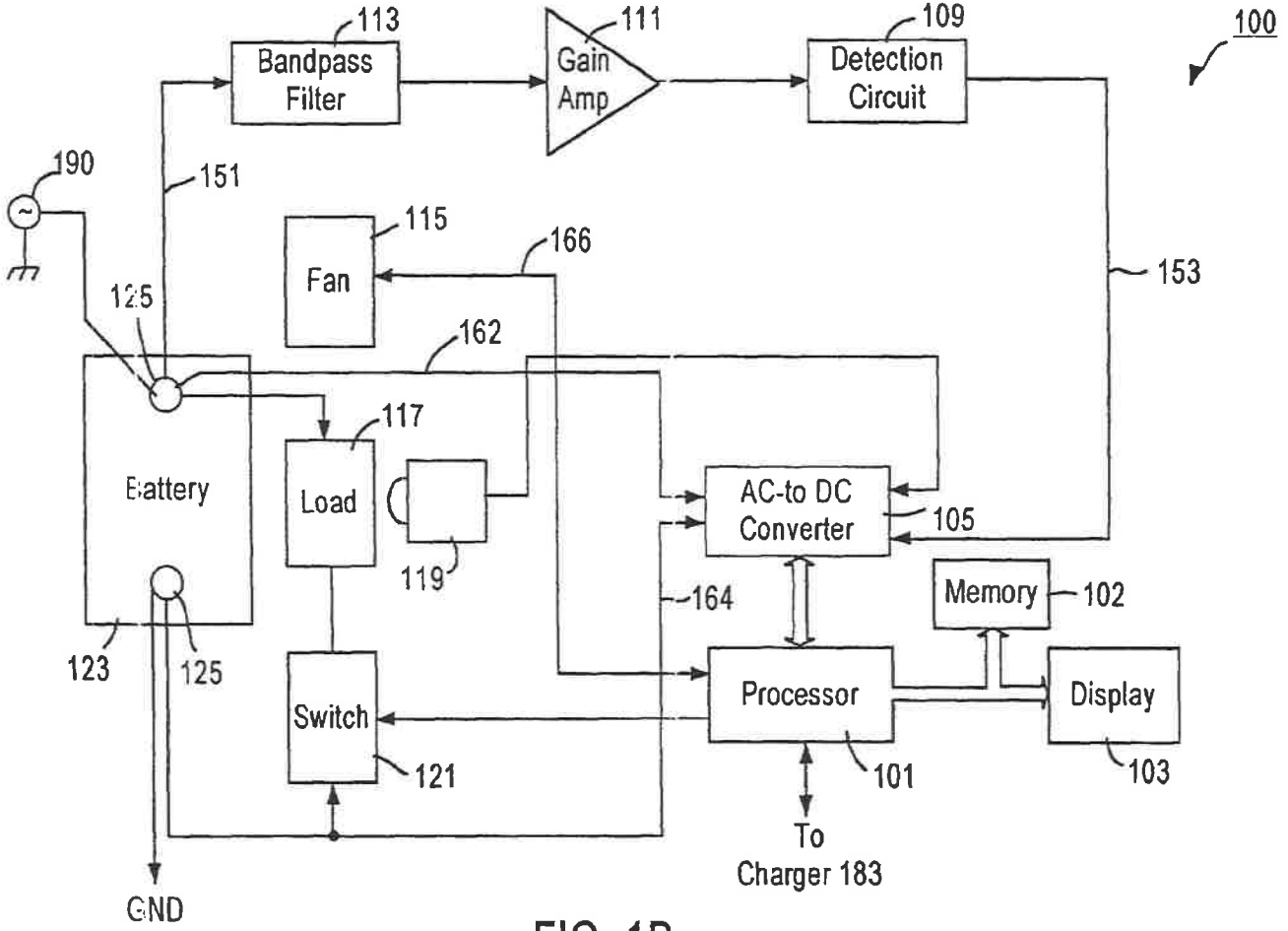
100
113
Bandpass Filter
111
Gain Amp
109
Detection Circuit
190
151
115
Fan
166
153
125
162
117
Battery
Load
119
AC-to DC Converter
105
164
Memory
102
123
125
Switch
121
Processor
101
Display
103
To Charger 183
GND

FIG. 1B

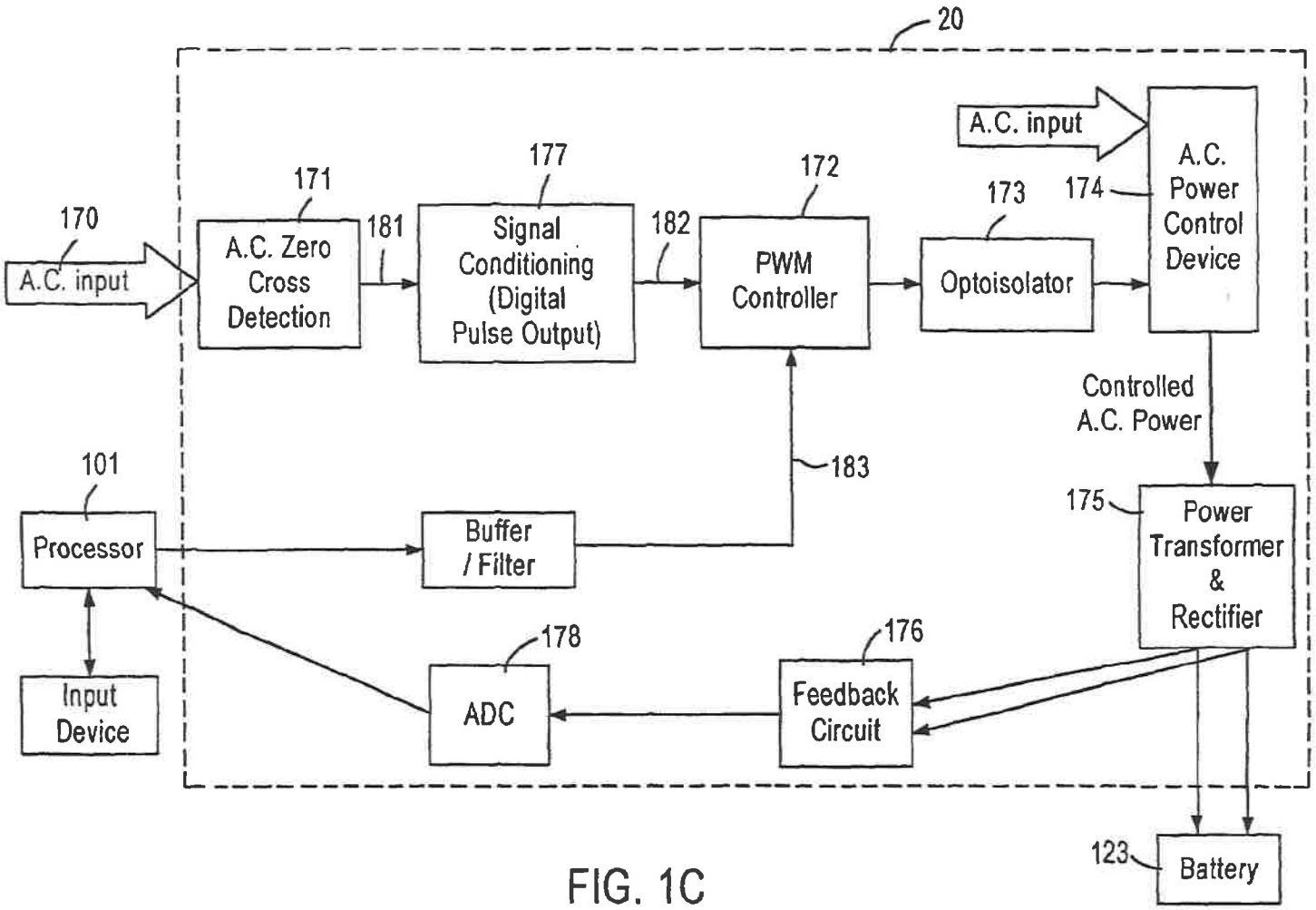
20
A.C. input
170
A.C. Zero Cross Detection
171
181
Signal Conditioning (Digital Pulse Output)
177
182
PWM Controller
172
173
Optoisolator
174
A.C. Power Control Device
A.C. input
Controlled A.C. Power
101
Processor
Buffer / Filter
183
175
Power Transformer & Rectifier
Input Device
178
ADC
176
Feedback Circuit
123
Battery

FIG. 1C

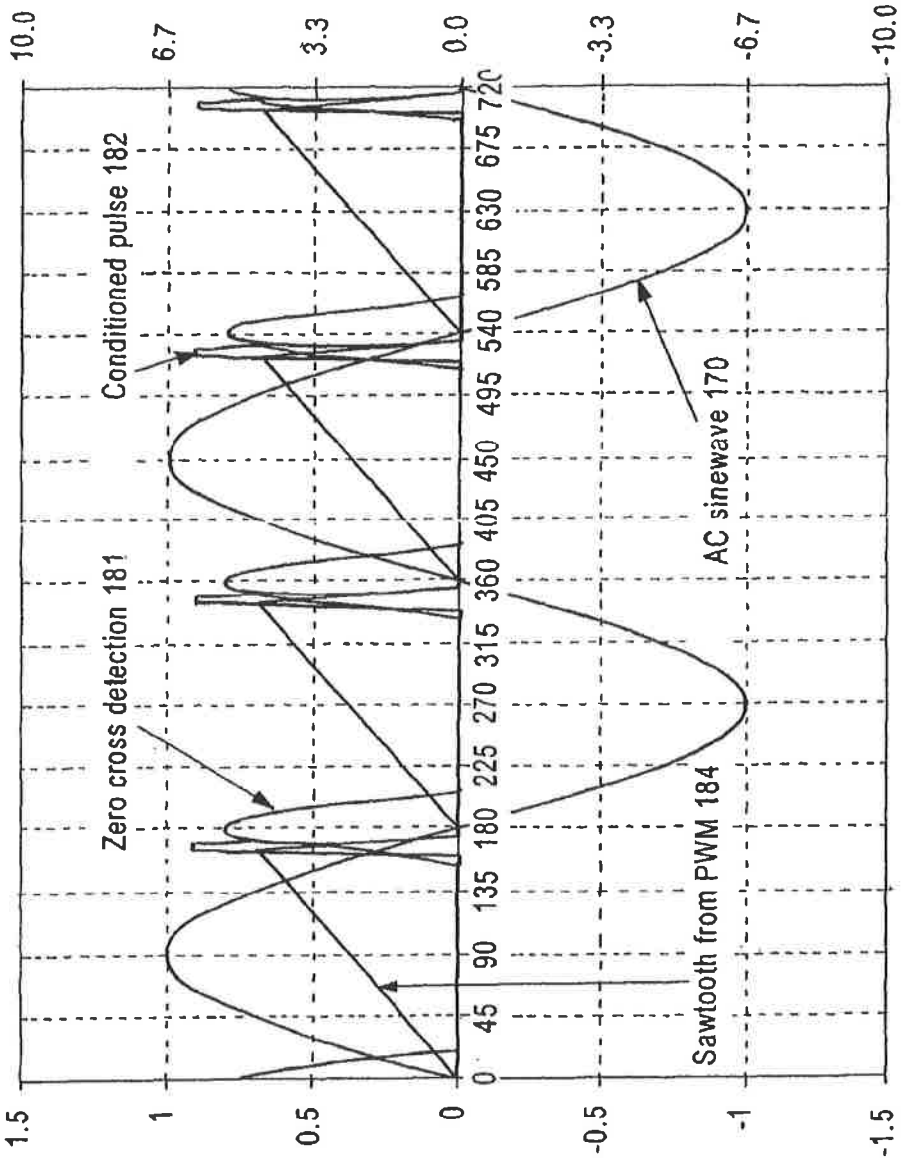
10.0
6.7
3.3
0.0
-3.3
-6.7
-10.0
1.5
1
0.5
0
-0.5
-1
-1.5
0
45
90
135
180
225
270
315
360
405
450
495
540
585
630
675
720
Conditioned pulse 182
Zero cross detection 181
AC sinewave 170
Sawtooth from PWM 184

FIG. 1D

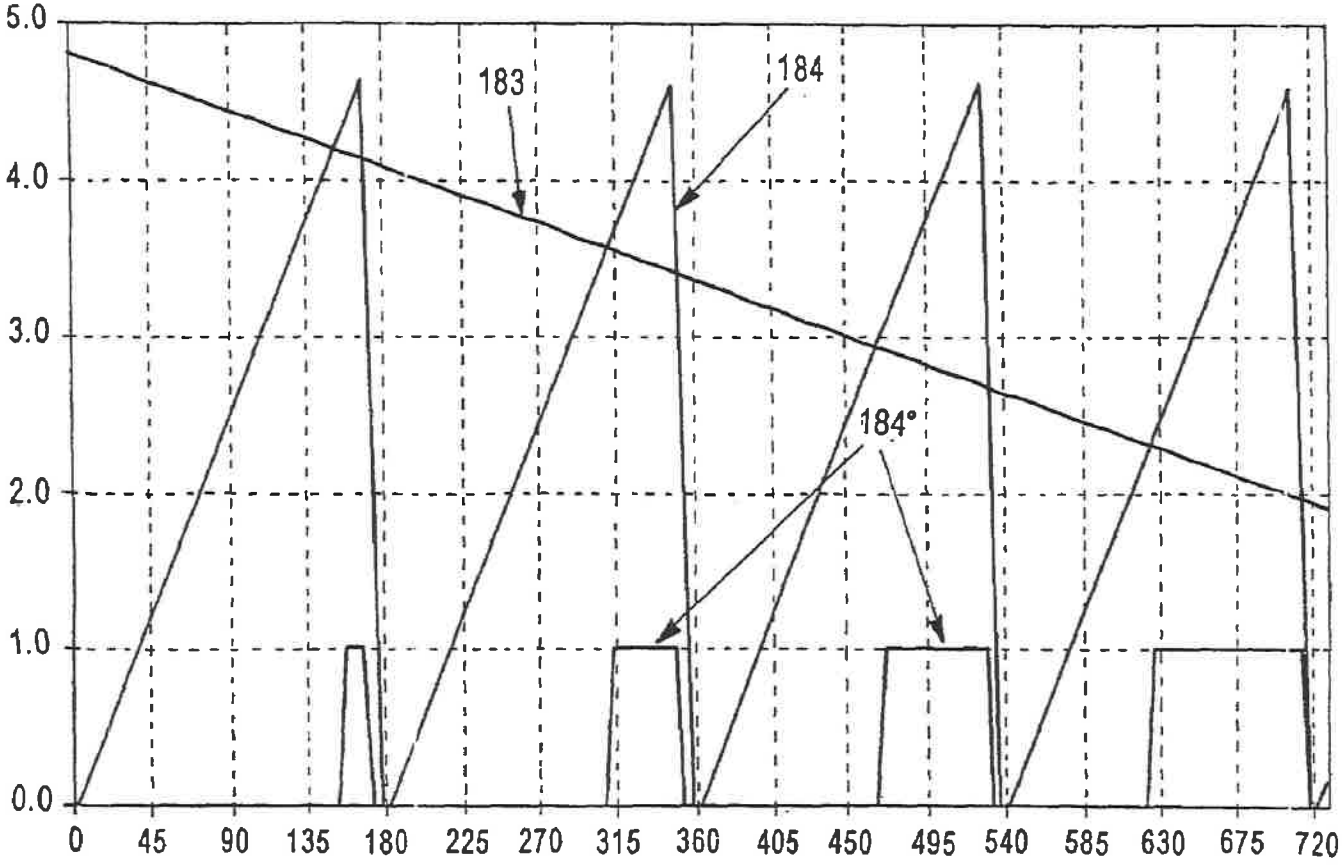
5.0
4.0
3.0
2.0
1.0
0.0
0
45
90
135
180
225
270
315
360
405
450
495
540
585
630
675
720
183
184
184'

FIG. 1E

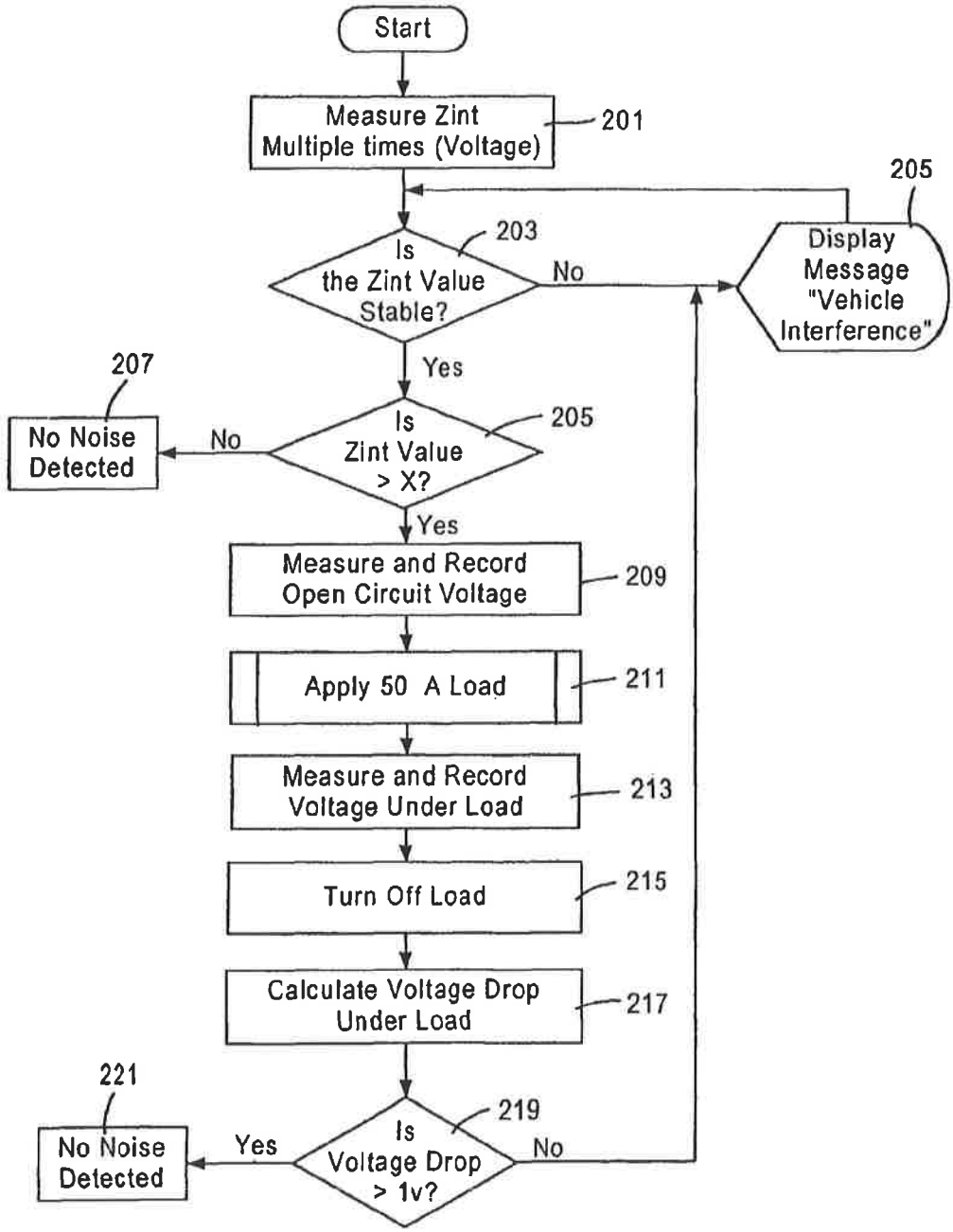
Start
Measure Zint Multiple times (Voltage)
201
205
Is the Zint Value Stable?
203
No
Display Message "Vehicle Interference"
Yes
207
No Noise Detected
No
Is Zint Value > X?
205
Yes
Measure and Record Open Circuit Voltage
209
Apply 50 A Load
211
Measure and Record Voltage Under Load
213
Turn Off Load
215
Calculate Voltage Drop Under Load
217
221
No Noise Detected
Yes
Is Voltage Drop > 1v?
219
No

FIG. 2

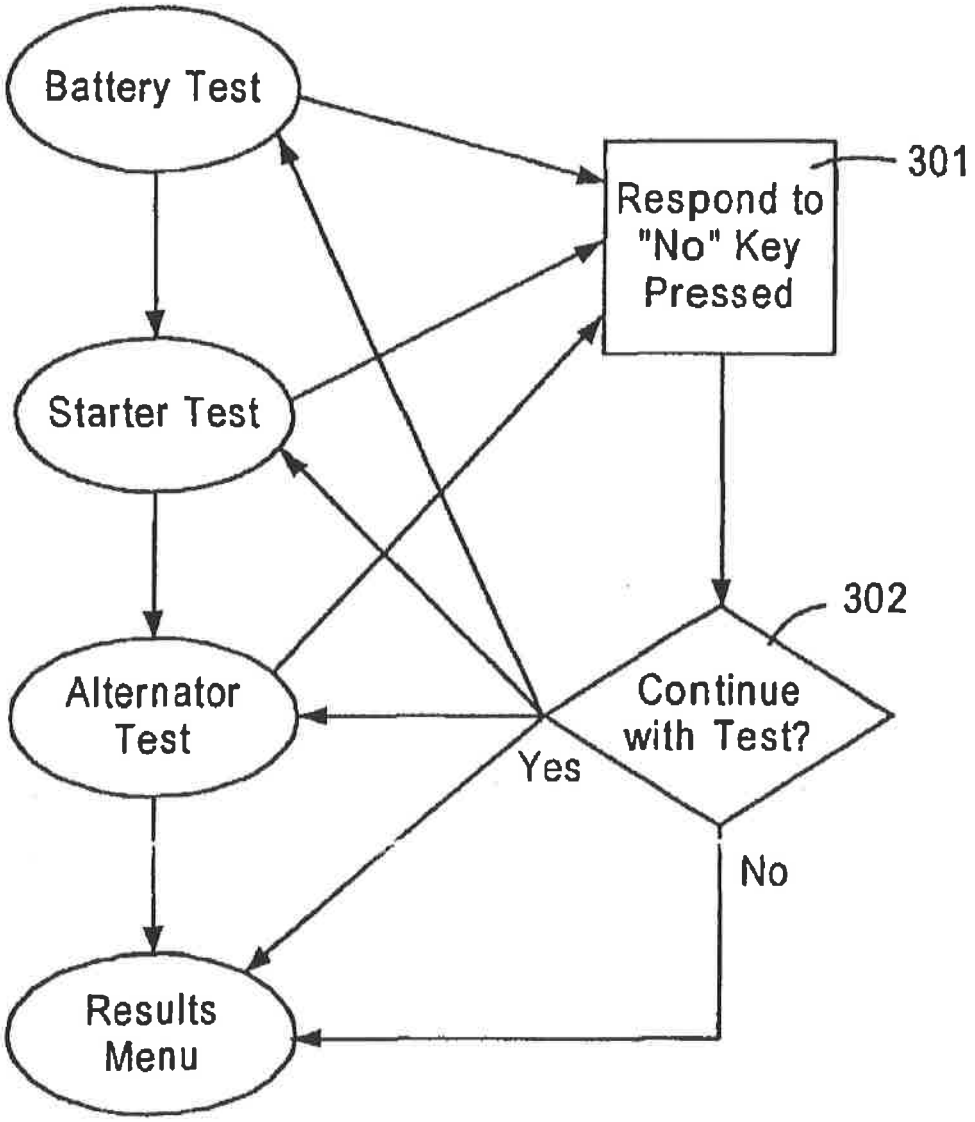
Battery Test
Respond to "No" Key Pressed
301
Starter Test
302
Alternator Test
Continue with Test?
Yes
No
Results Menu

FIG. 3

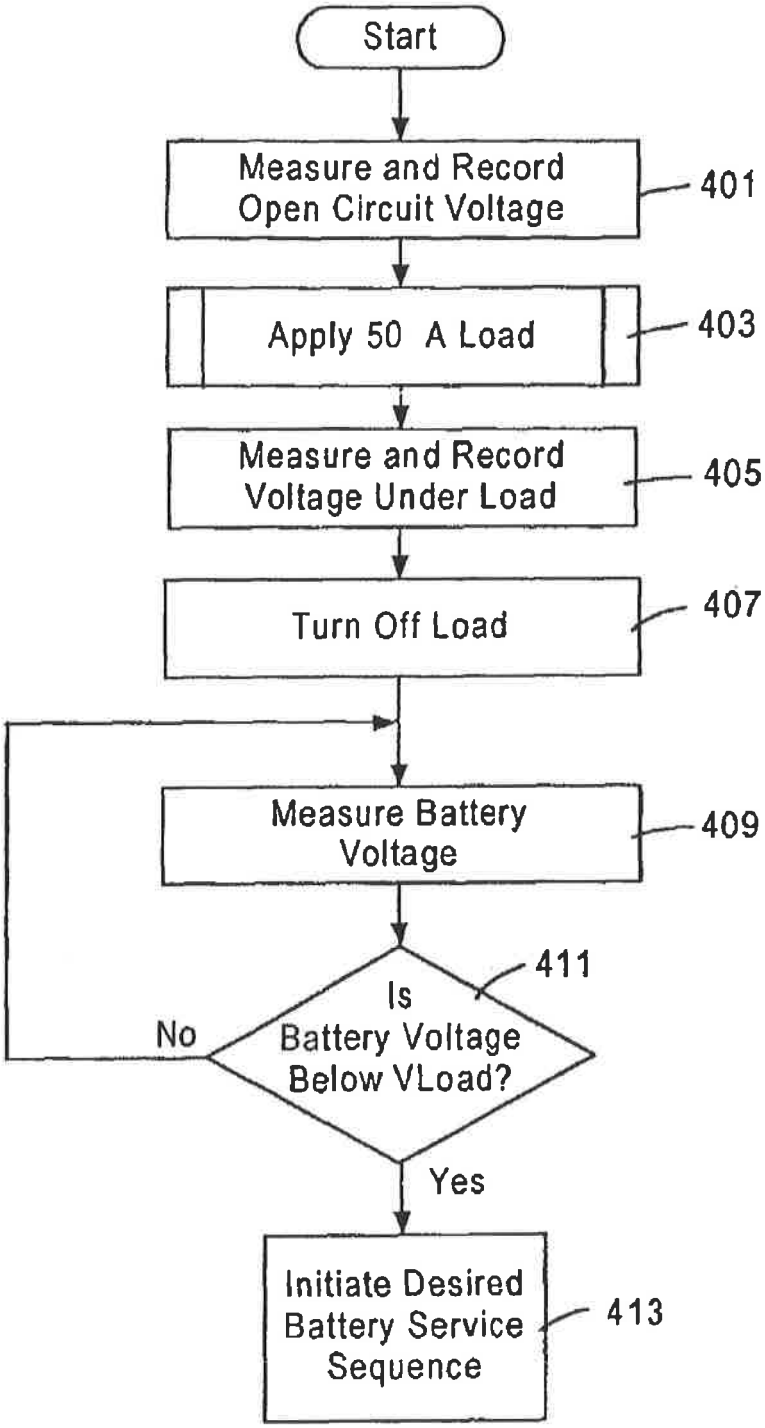
Start
Measure and Record Open Circuit Voltage
401
Apply 50 A Load
403
Measure and Record Voltage Under Load
405
Turn Off Load
407
Measure Battery Voltage
409
Is Battery Voltage Below VLoad?
411
No
Yes
Initiate Desired Battery Service Sequence
413

FIG. 4

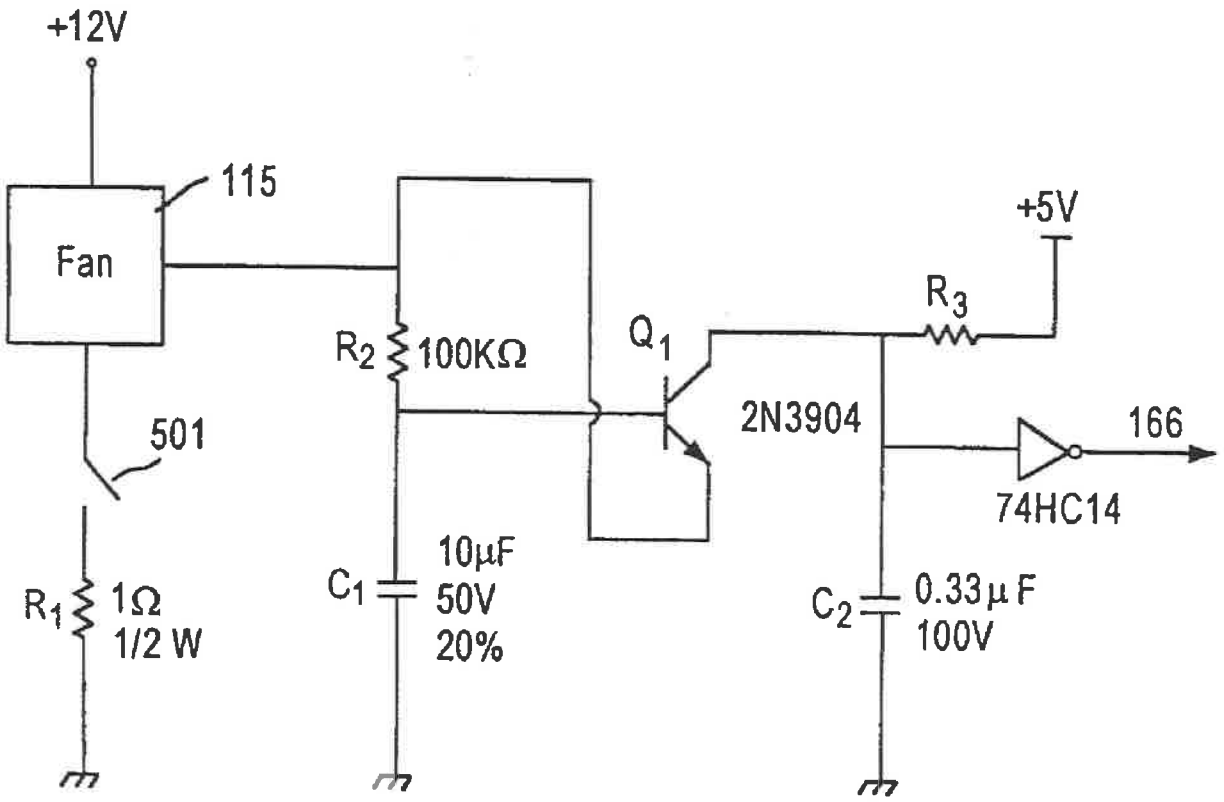
+12V
115
Fan
501
R1
1Ω
1/2 W
R2
100KΩ
C1
10μF
50V
20%
Q1
2N3904
+5V
R3
166
74HC14
C2
0.33μF
100V

FIG. 5

INTEGRATED BATTERY SERVICE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a Continuation Application of U.S. application Ser. No. 11/060,323, filed on Feb. 18, 2005, entitled "Integrated Battery Service System," which is a Division of U.S. application Ser. No. 10/460,652, filed on Jun. 13, 2003, entitled "Integrated Service Battery System," now U.S. Pat. No. 7,089,127. This Patent claims the benefit of priority from Provisional Application No. 60/387,912, filed on Jun. 13, 2002; entitled "Integrated Battery System," now expired. This application hereby incorporates in their entireties the disclosures of U.S. application Ser. No. 11/060,323, U.S. application Ser. No. 10/460,652, and U.S. Provisional Application 60/387,912.

FIELD OF THE DISCLOSURE

The disclosure relates generally to a battery service system, and more specifically, to an integrated battery service system that provides advanced control for servicing rechargeable batteries as well as components coupled to the battery based on signals obtained from the battery.

BACKGROUND OF THE DISCLOSURE

Conventionally, battery testers are implemented as a single-function system used exclusively for testing battery conditions. Some newer systems combine battery testing functions with battery charging functions such that rechargeable batteries are tested before being charged to distinguish bad batteries from good batteries, as bad batteries are incapable of delivering or accepting adequate charge. The functions of these newer systems are limited to servicing the battery only, and do not extend their functions to test other devices and/or components that are coupled to a rechargeable battery, such as alternators, starters and the like in a motor vehicle.

Furthermore, the service process of a conventional battery tester tends to be lengthy. If the service process is interrupted or aborted for any reason, the user has to start the whole process all over again, which will reduce productivity. In addition, conventional battery testing process is subject to noise interference, especially from components, sub-systems, and/or devices coupled to the battery. For example, in a motor vehicle, noise signals generated by the operation of a stereo system and/or fans that coupled to the battery may enter the battery tester during a battery test process and interfere with the test result.

Therefore, there is a need to provide an integrated battery service system to service the battery as well as various devices and/or components that are coupled to the battery. There is another need for a battery service system that allows users to resume an aborted testing process from where it was aborted without the need to conduct the whole test all over again. There is also a need for a reliable battery service system that takes noise signals into consideration when testing batteries.

SUMMARY OF THE DISCLOSURE

An exemplary integrated battery service system disclosed herein addresses the above noted needs as well as other needs and problems. The integrated battery service system is configured to perform a plurality of services related to a battery, such as battery testing, battery charging, and the like. In addition, the integrated service system provides services to devices/components that are coupled to the battery, such as starters, alternators, etc. The integrated battery service system may allow a user to terminate a service process and then resume the process from where the process was terminated. When conducting a battery service process, the integrated battery service system may consider noise signals generated by devices/components coupled to the battery.

An exemplary integrated battery service system includes connectors configured to couple to a battery for receiving input signals, a processor coupled to the connectors, and a memory device coupled to the processor for storing data. The battery service system has an alternator testing circuit coupled to the connectors and the processor for determining an operation status of an alternator based on the input signals. The integrated battery service system also provides other service functions, such as starter tests, battery charging, noise detection, etc.

In one aspect, the battery testing circuit includes a signal source coupled to the battery that continuously generates signals with time variant components configured to apply to the battery. The signal source may be an oscillator that continuously generates an AC signal when the battery service system is powered on. The processor is configured to receive signals representing a battery response to the signals with time variant components and to generate a battery parameter based on the battery response to the signals with time variant components. For instance, based on the battery's response to the AC signal generated by the oscillator, the processor calculates impedance/conductance of the battery. The integrated battery service system may determine the health of the battery based on the impedance/conductance of the battery. The AC signal is kept on until the system is powered off. The processor periodically or continuously calculates impedance/conductance of the battery and provides the results to a user of the system. The memory may be configured to store a history of the battery parameter and an output device may be provided to generate an output representing the history of the battery parameter.

According to an embodiment, a battery service system according to this disclosure includes connectors configured to couple to a battery, a processor for executing control codes and a memory device coupled to the processor for storing the control codes. The memory is configured to store service histories. The control codes, when executed by the processor, control the system to selectively abort a service process in response to a user input. Since the memory stores the history of the service process, the processor may access the memory to retrieve data related to the aborted service and parameters obtained during the service process before the process was aborted. The system continues the aborted battery service in response to another user input. Thus, a user of the system may freely abort a service process and then resume the process from where the process was stopped. In one aspect, the battery service system may abort or stop a service process automatically in response to a specific event, such as the connectors being removed from the battery terminals. The battery service system may continue the aborted service process after proper connections between the battery service system and the battery are restored.

According to another embodiment, an exemplary integrated battery service system determines the level of noise appearing during a test process. The battery service system comprises connectors configured to connect to the battery for receiving input signals, a processor and a memory device for storing a first reference parameter. The processor is configured to execute control codes that control the processor to

obtain multiple battery parameters by determining a battery parameter based on the input signals multiple times; and determine a testing condition based on the first reference parameter, the multiple battery parameters, and a determination rule. In one aspect, the battery parameter is the impedance of the battery, the first reference parameter is a specific range, and the determination rule requires that the variations of the multiple battery parameters fall within the specific range.

In another aspect, if the battery is stable, the processor compares the multiple battery parameters with a second reference parameter. The processor may determine the battery as stable if the changes of the multiple battery parameters fall within the specific range.

According to still another aspect, the processor is configured to carry out a plurality of service processes in response to the multiple battery parameters being larger than the second reference parameter. The service processes may include measuring an open circuit parameter of the battery based on the input signals; determining a battery response to a reference load coupled to the battery; decoupling the reference load from the battery; measuring a change in the battery response; and determining a test noise status based on the battery response.

According to another embodiment of the battery service system, the battery service system has a processor for executing control codes, a fan for dissipating heat, and a monitor circuit coupled to the fan and the processor for generating a signal indicating the operation status of the fan. In one aspect, in response to a signal indicating that the fan is not operating properly, the processor generates a warning signal.

Additional aspects and advantages of the present disclosure will become readily apparent to those skilled in this art from the following detailed description, wherein only exemplary embodiments of the present disclosure is shown and described, simply by way of illustration of the best mode contemplated for carrying out the present disclosure. As will be realized, the present disclosure is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the disclosure. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings in which like reference numerals refer to similar elements and in which:

FIGS. **1**A and **1**B show a block diagram of an integrated battery service system implemented according to the present disclosure under operation;

FIG. **1**C depicts a block diagram of a control circuit for controlling the charge level of the battery service system;

FIGS. **1**D and **1**E illustrate signal waveforms obtained at various points of the control circuit;

FIG. **2** is a flow chart illustrating the steps for determining the system noise status;

FIG. **3** illustrates a sequence of service processes provided by the battery service system;

FIG. **4** is a flow chart showing the steps of automated activation of service processes in response to a specific event; and

FIG. **5** is an exemplary circuit for monitoring the operation of the fan.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

For purpose of illustration, an exemplary integrated battery service system is described. The integrated battery service system provides advanced control for servicing rechargeable batteries as well as components coupled to the battery based on signals obtained from the battery. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the integrated battery service system. It will be apparent, however, to one skilled in the art that the invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

System Architecture

FIGS. **1**A and **1**B together show a block diagram of an integrated battery service system implemented under operation. For purpose of illustration, the operation of the integrated battery service system is described with a starter **182** and an alternator **181** of an automotive vehicle. In an automotive vehicle, the alternator **181** is driven by the engine of the automotive vehicle (not shown) to generate electricity. The output of the alternator **181** is coupled to a battery **123** via a set of battery terminals **125**. The starter **182** is also coupled to the battery terminals **125** for drawing currents to crank the engine in the automotive vehicle. A charger **183** coupled to the battery terminals **125** for charging the battery **123** is also shown. The charger **183** may be a part of the integrated battery service system **100**.

The integrated battery service system **100** has a set of connectors for connecting to the battery **123**. For example, the battery service system **100** may include a set of clamps (not shown) for connecting to the battery terminals **125** and receiving signals therefrom. The clamps may be implemented using Kelvin connectors that include a small conductor to a sense jaw and a large conductor to a load jaw.

The battery service system **100** utilizes a measurement circuitry (not shown in FIG. **1**B) to measure output signals obtained from the battery terminals **125** as well as from other signal paths. The measurement circuitry may include a voltage measurement circuitry and a current measurement circuitry that provide outputs to the processor **101** via test signal **162** and **164**. The test signals **162** and **164** may be voltage and/or current signals in AC and/or DC obtained from the battery terminals **125** by the connectors and/or other signal paths. The test signals **162**, **164** enter the processor **101** via an AC-to-DC converter **105**.

The battery service system **100** has a processor **101**, an analog-to-digital converter **105**, a memory device **102** and a display **103**. The processor **101** is configured to process data, execute control codes and generate control signals. The memory device **102** is coupled to the processor **101** for storing data and control codes. Different types of memory devices may be used or used in combination, such as volatile memory and/or non-volatile memory including a CD-ROM, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, a RAM, a PROM, EPROM, a FLASH-EPROM.

The analog-to-digital converter **105** converts analog signals to digital signals. The display **103** provides a communication interface with a user. The display **103** may be an LCD

screen, an LED indicator and/or the like. The service system **100** also includes an input device (not shown) coupled to the processor **101**. The input device may be control buttons, keyboards, cursor control devices, touch screen input devices, voice recognition devices, etc., or signals received from other systems connected to the battery service system **100**.

The battery service system **100** may include output connectors and/or interfaces for outputting signals to, or communicating with, other devices, such as serial port, parallel port, USB port, PS/2 port, IEEE-1394 port, infra red communication port, etc., and/or other proprietary ports.

The processor **101** may control a switch device **121**, such as an FET switch, that selectively couples a load **117** to the alternator. As illustrated in FIG. **1**B, switch device **121** and load **117** are serially connected and then coupled to the battery **123** in parallel via the battery terminals **125**. If the switch device **121** is on, the load **117** is coupled to the battery **123**; if the switch device **121** is off, the load **117** is decoupled from the battery **123**. Other circuit design techniques known to persons skilled in the art can be used for controlling the coupling of the load **117** to the battery **123**.

The load **117** may be any component that is capable of drawing large currents from the alternator, while maintaining small voltage across it. For example, the load **117** may include two Nichrome coils or carbon piles or a combination of both that are capable of drawing 50 amperes of current and 175 amperes of current, respectively. A Nichrome coil load is advantageous due to its ability to handle a substantial amount of current, while maintaining compact sizing.

The battery service system **100** has a signal source coupled to the connectors for continuously generating signals with time variant components configured to apply to the battery when the connectors are connected to the battery **123**. The signal source may be an oscillator **190** that continuously generates an AC signal when the battery service system **100** is powered on. The battery service system **100** continuously applies the AC signal to the battery **123**. The processor **101** receives signals representing a battery response to the AC signals with time variant components and calculates battery parameters based on the battery response to the AC signal.

A sensor **119** coupled to the AC-to-DC converter **105** is provided to detect the temperature of the load **117** and/or the system **110**, and convey the same to the processor **101**. A cooling device **115**, such as a cooling fan, may be provided to help dissipate heat generated by the load **117**. A signal **166** between the cooling device **115** and the processor **101** includes a control signal for controlling the operation of the cooling device **115** and/or a feedback signal indicating the operation status of the cooling device **115**.

A bandpass filter **113** is provided to eliminate harmonics as well as noise picked up at the battery terminals **125**. Bandpass filter **113** may have a pass band between 100 Hz and 4 kHz. A gain amplifier **111** is provided to amplify signal levels. A detection circuit **109** is coupled to the gain amplifier **111** and generates a parameter signal **153** representative of parameters obtained from the battery terminals **151**. The parameters are used by processor **101** to determine the characteristics of the battery **123** or devices coupled to the battery **123**, such as the alternator **181**. Techniques using parameters of alternator output signals to determine alternator operation are described in U.S. Pat. Nos. 3,629,704, 4,459,548, 4,315,204, and 6,242,921, the entireties of which are incorporated herein by reference.

Service Functions

The battery service system **100** performs numerous service functions related to the battery **123** as well as devices coupled to the battery **123**, such as the alternator **181** and the starter **182**. Examples of service functions provided by the integrated battery service system **100** are described below:

(1) System Test

The battery service system **100** provides a system test function. A system test is a series of tests conducted on the battery **123** and/or other systems or devices coupled to the battery, such as the alternator **181** and/or the starter **182**. The system test may include a battery test, an alternator test, and/or a starter test, and the like. Since the battery test can greatly influence the results of the other two tests, it is important to consider the battery test results when performing and evaluating those other tests. For example, the system test first tests the battery. If the battery passes the test, the battery service system **100** starts the starter test and/or the starter tester. If the battery test fails, the battery service system **100** either charges the battery or informs the operator of the battery failure by, for example, generating a warning signal on the display **103**. If the battery should be charged, the operator has the option to proceed charging the battery or to skip the charge cycle. In addition to the system test, the battery service system **100** may conduct these tests individually.

(2) Battery Testing and Charging

During an exemplary battery testing and charging procedure, the battery service system **100** performs the following steps:

A. Battery Test:

1) Check connections:

a) The processor **101** receives voltage and current obtained form the battery **123** via signals **162** and **164**.

b) The processor **101** determines if the battery **123** is connected and if all jaws have a good connection

2) The battery service system **100** receives operator inputs related to battery specifications, such as CCA, CA, DIN, EN input or other specifications regarding size of the battery **123** under test, via the user input device of the battery service system **100**.

3) Perform battery impedance test:

The battery service system **100** measures the battery internal impedance, also known as internal resistance. The processor **101** receives the battery's response to an AC signal generated by the AC oscillator **190**, and calculates the impedance of the battery **123** based on the AC signal and the battery's response thereto.

4) Perform load test:

a) During a load test event, the processor **101** turns on the fan **115** to assist dissipating heat generated during the load test.

b) The processor **101** sends a control signal to switch **121** to engage the load **117** to apply a 150 amp resistive load for several seconds.

c) The processor **101** then measures terminal loaded voltage via sense leads and the current.

d) The processor **101** then sends a control signal to switch **121** to disengages the load **117**.

e) The processor **101** then measures bounce-back voltage.

5) Determine battery test results

a) Based on parameters obtained in the previous steps, the processor **101** calculates battery test results.

b) If the battery **123** is determined good, the processor **101** controls to exit the battery test and indicate results on the display **103**.

c) If battery **123** is determined bad, the processor **101** controls to exit battery test and indicate results on the display **103**.

d) If battery **123** is determined marginal, the processor **101** controls to enter a battery charge routine.

B. Battery Charge

Battery charge is conducted by the charger **183**. The charger **183** generally includes an AC source, a transformer and a rectifier. The processor **101** couples the charger **183** to the battery **123** through electrical connection that couples to the positive terminal of the battery and to the negative terminal of battery **123**. In one embodiment, a four point (or Kelvin) connection technique is used in which the charger **183** is coupled to the battery while the battery testing circuitry couples to the battery.

The battery service system **100** provides four different charging modes: (1) Automatic charging; (2) Manual Charging; (3) Trickle Charging; and (4) Crank Assist Charging. Under the Automatic charging mode, the battery service system **100** automatically charges the battery **123** without user intervention. Under the Manual charging mode, the battery service system **100** provides a continuously adjustable voltage range to allow an operator to establish a target charging voltage. During the Manual charging mode, the battery service system **100** maintains the battery voltage at a specific level. The battery voltage level may be continuously adjusted by the operator. The Manual changing mode may be applied to batteries while repair is performed to the vehicles so that the battery voltage will not drop below minimum specifications when a computer relearn is necessary.

Another charge mode is the Trickle charge, this limits the current and voltage too much lower levels. This operation mode is optimal for small 12 Volt battery applications, such as motorcycle, lawn mower, etc. The Crank assist charging mode allows the battery service system **100** to boost start a vehicle. Under the Crank assist charging mode, the battery service system **100** will pre-charge the battery for 1-5 minutes, depending on the battery size, condition and temperature of the battery before allowing the user to attempt to start the disabled vehicle.

C. Variable Charge Level

The battery service system **100** provides a service function to charge the battery **123** at a charge level that is continually adjustable. For example, in the Manual charging mode as described earlier, the battery service system **100** allows an operator to establish a target charging voltage within a continually adjustable voltage range. In response, the battery service system **100** controls to increase/decrease the battery voltage until the target battery voltage is reached. The battery service system **100** then maintains the battery voltage at the target battery voltage.

FIG. **1**C depicts a block diagram of a control circuit **20** for controlling the charge level of the battery service system **100**. The control circuit **20** may be part of the charger **183** or as a separate circuit. FIGS. **1**D and **1**F illustrate signal waveforms obtained at various points of the control circuit **20**. A zero crossing detector **171** is provided to detect an a.c. line voltage zero crossing and responsively generate a pulse-like signal **181** to indicate a status of zero crossing. Signal **181** enters a signal conditioning device **177** that generates a signal **182** that contains a series of conditioned pulse based on the signal **181**. Signal **182** then enters a PWM (pulse width modulation) controller **172**, which also receives a signal **183** from the processor **101**.

Based on the signal **182**, the PWM controller generates a sawtooth signal **184** that is synchronized to the signal **182** that indicates to the zero crossing of the a.c. signal **170**. The processor **101** generates the signal **183** by converting its own PWM output to provide a rectangular wave output. That signal is buffered and filtered to create a variable d.c. voltage. The processor **101** alters the d.c. voltage level by changing the duty cycle of that PWM output signal of the processor **101**.

The PWM controller **172** utilizes a comparator to compare the level of the sawtooth signal **184** and the signal **183** which represents a variable d.c. voltage controlled by the processor **101**. In one embodiment, during the time periods where the amplitude of the sawtooth signal **184** is greater than the d.c. voltage represented by the signal **183**, the comparator controls the PWM controller **172** to output a low-state output. Otherwise, the comparator controls the PWM controller **172** to output a high-state output. When the output of the PWM controller **172** goes to a low-state, an optoisolator **173** is turned on; otherwise, the optoisolator **173** is turned off. Every time the optoisolator **173** is turned on, it triggers a power control device **174**, such as an alternistor, which in turn controls the power transformer and rectifier **175** to charge the battery **123**. The power control device **174** is turned on and off repeatedly based on the output of the optisolator **173**. Signal **184** in Fig. E shows the on period of the optoisolator **173**. The control circuit **20** provides feedback signals of the battery voltage through a feedback circuit **176**. The feedback signals then pass an ac-to-dc converter **178** and enter the processor **101**.

During operation, a user enters uses the input device to enter a target battery voltage. The processor **101** compares the battery voltage obtained from the feedback circuit **176** with the target battery voltage set by the user. In response to the battery voltage being lower than the target battery voltage, the processor **101** changes the level of signal **183** to increase the on time of the alternistor during the half cycle of a.c. power. For example, the processor **101** may decrease the level of signal **183**. In response, the alternistor is turned on earlier, and power is applied to the transformer earlier in each half cycle. Therefore, the voltage output to charge the battery **123** is higher. If the processor **101** detects that the battery voltage has reached, or has an tendency to exceed, the target battery voltage, the processor **101** may start to increase the level of signal **183**, which will in turn reduce the voltage output to charge the battery **123**.

In addition to the steps described above, other approaches for determining the battery charging status and controlling of battery charging may be used to implement the battery service system **100**. For example, the impedance and/or conductance of the battery can be used to determine if the battery needs to be charged. In one embodiment, if the impedance and/or conductance is greater than a predetermined threshold, it indicates that the battery probably is not in a good condition. Further, an initial load test may be applied to the battery using load resistance to determine if there is a bad cell by observing a resultant decline in voltage versus time using the voltage measurement circuitry. Other well known techniques in testing and charging the battery can also be used to implement the battery service system.

3. Starter Test

In a starter test, the battery service system **100** monitors the voltage at the battery **123** expecting to detect a drop in the voltage level due to the high level of current that the starter **182** takes from the battery. A starter in poor condition will draw more current, which in turn will cause excessive deviation in the battery voltage level.

The battery service system **100** can perform two types of starter tests. The first type of test is a Normal starter test, and the second type of test is an Extended starter test. During the Normal starter test, the ignition system is not disabled for measuring a cranking voltage, while during the Extended starter test, the ignition system is disabled and a current draw reading is obtained.

During the starter test, the battery service system **100** measures the open circuit battery voltage of the battery **123**. The

battery service system **100** then prompts the operator to start the engine. The starter **182** is evaluated by the amount of voltage drop that occurs in comparison to the voltage and state of charge of the battery. An exemplary starter test procedure is provided in below:

1) The processor **101** controls to engage the a 50 amp load to the battery **123**.
2) The battery service system **100** monitors the battery voltage while the load is applied.
3) The processor **101** controls to disengage the 50 amp load from the battery **123**.
4) The processor **101** prompts the operator to start the engine.
5) The battery service system **100** monitors the battery voltage.
6) The processor **101** evaluates the starter **182** based on the amount of voltage drop that occurs in comparison to the voltage and state of charge of the battery.

4. Alternator Test

The alternator **181** is driven by the engine to generate AC power to charge the battery. The battery service system **100** provides a service process to test the health of the alternator. According to one embodiment, the battery service system **100** measures the frequency of a signal taken from the battery terminals **125**, which contains an a.c. component that originates from a rectified output from the alternator **181**. The battery service system **100** evaluates the frequency measurement to determine the condition of the diodes of the alternator **181** as well as the speed at which the alternator is running.

For example, the battery service system **100** filters a ripple component of the alternator output using bandpass filter **113**, gain amplifier **111** and detection circuit **109**. The ripple frequency is detected and compared with a threshold frequency. If the ripple frequency is lower than the threshold frequency, it is determined that at least one diode in the alternator's rectifier is defective. In order to calculate the ripple frequency, the ripple voltage is compared with a threshold voltage to count the crossings. An adaptive threshold voltage based on the ripple voltage levels may be used to reduce errors due to the frequent change in the ripple voltage levels.

In another instance, the processor **101** monitors the battery voltage while a 50 amp load is applied. This 50 amp load will cause a bad alternator output to reduce from the typical voltage of about 14 volts. The 50 A load is used to stabilize the output signal to better measure its frequency. The test is conducted at an idle engine speed as well at a raised RPM level. The battery service system **100** prompts the user to start the engine and to increase the RPM rate. Insufficient or excessive battery voltage indicates a fault in the alternator **181**.

Details of methods and circuits for determining the health of an alternator based on signals obtained from battery terminals are described in U.S. patent application Ser. No. 09/888,385, filed Jun. 26, 2001, entitled "Alternator Testing Method and System Using Ripple Detection," and to U.S. patent application Ser. No. 09/888,382, filed Jun. 26, 2001, entitled "Alternator Testing Method and System Using Timed Application of Load," and to U.S. provisional Patent Application No. 60/214,254, filed Jun. 26, 200, entitled "AUTOMATIC ELECTRICAL SYSTEM TESTING APPARATUS AND METHODS," assigned to the assignee of the present invention, all of which are incorporated herein by reference.

An exemplary alternator test procedure is provided in the following:

1) The processor **101** controls the switch **121** to apply a 50 amp load to the battery **123** to cause significant current flow.
2) The battery service system **100** monitors battery voltage while the load is applied.
3) The processor **101** controls the switch **121** to disengage the 50 amp load from the battery **123**.
4) The battery service system **100** prompts the operator start the engine.
5) The battery service system **100** monitors the battery voltage drop. A drop in the battery voltage greater than the loaded voltage indicates that the starter is engaged.
6) The battery service system **100** measures the alternator frequency when the engine is at idle.
7) The battery service system **100** measures battery voltage and peak voltages and frequency when the engine is at idle.
8) The battery service system **100** prompts the operator to increase RPM of the engine.
9) The battery service system **100** measures the alternator frequency.
10) The battery service system **100** measures battery and peak voltages at the increased RPM.
11) The processor **101** controls the switch **121** to apply the 50 Amp load to the battery **123**.
12) The battery service system **100** measures battery and peak voltage and frequency at increased RPM while load is applied.
13) The processor **101** controls the switch **121** to remove the 50 Amp load from the battery **123**.
14) The processor **101** evaluates the alternator based on the values of the various voltage readings.

5. Noise Determination

As the battery **123** is connected to other parts of the automotive vehicle, system noise from other parts or circuits of the automotive vehicle that are coupled to the battery may appear on the battery terminals. Such system noise may affect the test results. The battery service system **100** provides a noise determination test to determine the status of system noise. If the system noise will affect the test result, a warning message may be generated to alert the operator. Otherwise, services on the battery will proceed.

FIG. **2** is a flow chart showing the steps for determining the system noise status. Multiple impedance measurements are taken to detect the presence of varying voltage at the battery terminals. The voltages appearing on the battery terminals are related to battery impedance as well as noise of the vehicle. Voltage variations are caused by various circuits being activated within the automobiles electrical system. This 'noise' can interfere with the impedance measurements.

The battery service system **100** measures battery impedance multiple times (Step **201**) and determines if the impedance measurements are stable (Step **203**). If the measurements are not stable, it implies that the system noise may affect the readings. The battery service system may generate a warning message (Step **205**).

In order to determine whether the impedance measurements are stable, the processor may compare variations of the impedance measurements with a first reference parameter, such as an acceptable tolerance range. If the variations in the impedance readings fall within the acceptable tolerance range, the impedance readings are consider as stable. Different types of batteries may have different tolerance ranges. Based on the type of battery under test, proper tolerance range may be obtained empirically.

Examples for acceptable tolerance range for different types of batteries are:

100-399 CCA; a maximum of 0.20 milliohm
1200-1500 CCA; a maximum of 0.05 milliohm

If the impedance fluctuation is less than the tolerance range, it may preliminarily be determined that the system noise will not affect the battery service. However, consistent high system noise may also contribute to stable impedance readings.

In order to prevent false determination, the processor **101** compares the detected impedance with a second reference parameter, such as a reference impedance (step **205**). As an example, the reference impedance may be set at 30 milliohm. If the detected impedance is smaller than the reference impedance, it is implied that no excessive system noise contributes to the stable impedance reading (Step **207**). Thus, the determination is reliable. On the other hand, if the impedance reading is larger than the reference impedance, it is possible that excessively high system noise may have contributed to the stable impedance reading.

In order to determine whether system noise contributes to the stable impedance reading, the battery service system further applies a load (50 Amp) and further monitors the voltage amplitudes of both DC and the time varying component at the battery (Steps **209-213**). The 50-Amp load is then removed and a corresponding voltage drop is measured (Steps **215** and **217**). Since system noise is not affected by the 50-Amp load, the measured voltage drop will be small. Thus, a small voltage drop implies that the system noise affects the impedance reading. On the other hand, if the voltage drop is large, it implies that high battery impedance contributes to the high voltage drop and the system noise does not significantly affect the impedance readings. The processor **101** compares the measured voltage drop with a third reference parameter, such as a reference voltage drop greater than 1 Volt (Step **219**). If the measured voltage drop is larger than the reference voltage drop, the processor **101** determines that the system noise is acceptable (Step **221**). Otherwise, the system noise is not acceptable and a warning message may be generated (Step **205**).

6. Multimeter

The battery service system **100** also provides a multimeter for displaying values and/or waveforms of input signals on the display **103**. The battery service system **100** may provide separate external current probes for making non-intrusive current measurements. The multimeter function may include an impedance measurement screen and a battery manual load test that allows the operator to apply the load for a period of time set by the operator.

Control of Operation Sequence

FIG. **3** illustrates a sequence of service processes provided by the battery service system **100**. The battery service system **100** performs the service processes, including a battery test, a starter test, and an alternator test, in a sequence. During operation, the processor **101** keeps tracking the service process status and saves the status in the memory **102**. The battery service system **100** allows the operator to abort a service process and continue to finish the process if he chooses to. For example, the operator may push a "No" key to indicate aborting an active service process, such as the starter test (Step **301**). In response, the processor **101** set a flag in the memory indicating the aborted event and saved the test data related to the aborted service process in the memory **102**.

When the operator indicates reinstating the aborted sequence, such by pushing a "Continue" button (Step **302**), the processor **101** accesses the status and test data stored in the memory **102**, and continues the aborted process accordingly. According to one embodiment, the battery service system **100** allows the operator to terminate the aborted sequence. According to another embodiment, the battery service system **100** allows the operator to abort a procedure entirely, and then continue with other tests in the sequence. Test data that has already been gathered is saved in the memory **102** and can be used in other tests at a later time. For example, a user may use the battery service system **100** to conduct a battery test, but then decides to abort the battery test and conducts an alternator test instead. Test data collected during the battery test process, such as measurements, user inputs, etc., can be used in the alternator test, if applicable. Therefore, the user does not need to gather the same data again.

The battery service system **100** may generate a report to the operator providing all the information obtained up to the point where the sequence was terminated. The battery is tested under various loads, RPMs, and operating conditions of the engine. These measurements are stored and then evaluated to determine the condition of the battery.

According to another embodiment, the battery service system may abort or stop a service process automatically in response to a specific event or events, such as the connectors being removed from the battery terminals, the power of the battery service system **100** is low, etc. The specific event or events may be preset by the battery service system **100** and/or by users. The battery service system may continue the aborted service process in response to another event, such as a pushed button or a system detection indicating that proper connections between the battery service system and the battery are restored.

Activation of Service Sequences

The battery service system **100** provides automated activation of service processes in response to a specific event. For example, the battery service system **100** may start a battery service process when the operator turns the ignition key of the automotive vehicle. The service procedure starts in response to the system detecting a very slight change in the battery voltage. However, other events can also cause a voltage change prior to the key being turned (i.e. opening the door and have several bulbs turn on). To avoid that mistake, the battery service system **100** utilizes a threshold reference to assist identify the specific event.

FIG. **4** is a flow chart showing the steps of automated activation of service processes in response to a specific event. In Step **401**, the battery service system **100** measures and records open circuit voltage of the battery **123**. The battery service system **100** then applies a 50 Amp load to the battery **123** (Step **403**). The processor **101** then measures a reference battery parameter, such as the battery's terminal voltage, under the 50-Amp load (Step **405**). That measurement is stored in the memory **103** and used as a threshold that is referenced in determining when an item is activated that will draw 50 or more amps. When the engine is turned on, the starter **182** will typically draw 100-200 amps. Thus, the voltage drop on the battery output will be more significant than that under the 50-Amp load. In Steps **409** and **411**, the processor **101** measures a battery parameter, such as the output battery voltage, and compares the output battery voltage with the battery's terminal voltage under the 50-Amp load. If the voltage drop is more than the voltage drop under the 50-Amp load, it indicates that the operator has turned on the engine. In response, the battery service system **100** starts the desired battery service process the service process based on system settings (Step **413**). On the other hand, if the voltage drop is less than the threshold reference voltage, the battery service

system **100** determines that the voltage drop comes from system noise and will not start the battery service process.

Control of Heat Dissipating Fan

Referring to FIG. **1**B, the battery service system **100** has a fan **115** to help dissipate heat generated during the operation of the system **100**. If the fan **115** does not work normally, the heat generated by the system **100** cannot be dissipated properly. The heat will cause malfunction of the components and the system **100**.

The processor **101** controls the ON/OFF status of the fan **115**. A temperature sensor **119** may be provided to monitor the system temperature. When the temperature is too high, the processor **101** turns on the fan **115**; otherwise, the fan **115** is turned off. Alternatively, the fan **115** may be kept always on when the system **100** operates.

The battery service system **100** has a detection circuit (not shown in FIG. **1**B) to monitor the operation of the fan **115**. If the fan fails or is blocked, this circuit will provide a feedback signal **166** to the processor to indicate as such. In response, the processor **101** will alert the operator to prevent damage to the system **100**.

FIG. **5** is an exemplary circuit for monitoring the operation of the fan **115**. A +12 volt source is controlled by a switch **501**, such as a transistor. When the switch **501** is turned on, current flows through the fan **115** and the 1 ohm resistor. The operational nature of the fan causes a pulsing current, which causes a voltage drop when the pulsing current passes through the 1 ohm resistor. The voltage drop causes a current to pass through R**2** and charge C**1**, which creates a small voltage level at the base of transistor Q**1**. The voltage at the 1 ohm resistor is also connected to the emitter of transistor Q**1**. The variation of the voltage drop along with the voltage applied to the base of Q**1** causes Q**1** to switch between its conductive and non-conductive states.

A +5 volt level is applied to R**3** and a current flows through it and charges C**2**. If the fan **115** is not running, Q**1** never turns on and C**2** charges to approximately +5 volts. The inverter translates that voltage level to a zero volt level, which is fed back to the processor **101** through signal path **166**. The processor **101** interprets that signal as an indication that the fan is not running. If the fan **115** is running, Q**1** repeatedly turns on and off and discharges C**2** to the extent that the voltage level is below the switching threshold voltage of the inverter. Therefore the inverter puts out a +5 volt level that the processor interprets as the fan is running.

Obtaining Battery Parameters

The battery service system **100** may continuously obtain battery parameters. For example, the battery service system **100** may be configured to apply an AC signal generated by the AC oscillator **190** to the connectors as soon as the system **100** is turned on. As the AC signal is applied to the battery continuously, the processor **101** may continuously obtain the battery's response to the AC signal generated by the AC oscillator and keep track of impedance/conductance readings over time. Since the battery parameters are obtained not only during battery testing, but also on a continuous basis, the obtained parameters collectively provide a better view of the battery status. The impedance/conductance readings over time can be accessed by the operator to assist determination of system noise and/or changes in battery impedance/conductance.

The embodiments described above may be used with any desired system or engine. Those systems or engines may comprise items utilizing fossil fuels, such as gasoline, natural gas, propane and the like, wind and hybrids or combinations thereof. Those systems or engines may be incorporated into other systems, such as an automobile, a truck, a boat or ship, a motorcycle, a generator, an airplane and the like. The embodiments may include or be utilized with any appropriate voltage level, such as about 12 Volts, about 42 Volts and the like.

Software implementing the functions of the battery service system **100** as described in this disclosure may be stored in the memory **102** and/or a machine-readable storage medium, such as optical disks, hard disks, tapes, etc. The machine-readable storage medium may be distributed to customers who want to use the battery service system **100**. The software may also be distributed via the Internet. Customers may download the software from a web site and install the programs on their own systems. The machine-readable storage medium may be implemented as memory card and/or memory cartridge that can be inserted into the battery service system **100** and are accessible by the processor **101**.

While this invention has been described in connection with an exemplary embodiment, it is to be understood that the invention is not limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed:

1. A system for conducting a service on a vehicle, the system comprising:
- connectors configured to couple to a battery of the vehicle;
- an input device;
- a processor coupled to the connectors and the input device for executing control codes to carry out the service; and
- a memory device coupled to the processor for storing the control codes and recorded information related to an interruption point in the service,
- wherein the control codes, when executed by the processor, control the system to:
  - access the information related to the interruption point in the service; and
  - resume the service from the interruption point,
- wherein the service is a battery test service, an alternator test or a starter test, and
- wherein the control codes, upon execution by the processor, control the battery service system to perform the battery test, the starter test, the alternator test, and a battery charge service in a predetermined sequence.

2. The system of claim **1**, wherein the processor generates a report providing information obtained up to the interruption point.

3. The system of claim **1**, wherein the processor generates a report providing information obtained from the resumption of the service.

4. A system for conducting a service on a vehicle, the system comprising:
- connectors configured to couple to a battery of the vehicle;
- an input device;
- a processor coupled to the connectors and the input device for executing control codes to carry out the service; and
- a memory device coupled to the processor for storing the control codes and recorded information related to an interruption point in the service,
- wherein the control codes, when executed by the processor, control the system to:
  - access the information related to the interruption point in the service; and
  - resume the service from the interruption point,

wherein the service is a battery test service, an alternator test or a starter test, and

wherein the control codes, upon execution of by the processor, control the battery service system to sequentially perform the battery test, the starter test, the alternator test, and a battery charge service.

5. A battery service system comprising:

a processor configured to receive signals from connectors coupled to a battery;

an input device coupled to the processor;

a display coupled to the processor;

a memory configured to store control codes; and

an interface for communicating with other devices, the interface comprising one or more of a USB port, a serial port, and an IEEE-1394 port,

wherein the processor executes the control codes to continually adjust a charge level applied to the battery.

6. The battery service system of claim 5 further comprising a measurement circuit coupled to the processor, wherein the charge level is continually adjusted based on measurements from the measurement circuit.

7. The battery service system of claim 6, wherein the measurement circuit measures a voltage signal.

8. The battery service system of claim 6, wherein the measurement circuit measures a current signal.

9. The battery service system of claim 6 further comprising a feedback circuit to the processor, wherein the charge level is continually adjusted based on the feedback provided by the feedback circuit.

10. The battery service system of claim 5, wherein the memory device is configured to store history information.

11. The battery service system of claim 5, wherein the memory comprises non-volatile memory.

12. The battery service system of claim 11, wherein the memory comprises FLASH memory.

13. The battery service system of claim 5, wherein the display comprises an LCD display.

14. The battery service system of claim 13, wherein the display further comprises an LED indicator.

15. A system for conducting a service on a vehicle, the system comprising, a processor configured to receive signals from connectors coupled to a battery; an input device coupled to the processor; a display coupled to the processor; a memory configured to store control codes; and wherein a wireless interface is for communicating with other devices, wherein the processor executes the control codes to continually adjust a charge level applied to the battery.

16. The battery service system of claim 15 further comprising a measurement circuit coupled to the processor, wherein the charge level is continually adjusted based on measurements from the measurement circuit.

17. The battery service system of claim 16, wherein the measurement circuit measures a voltage signal.

18. The battery service system of claim 16, wherein the measurement circuit measures a current signal.

19. The battery service system of claim 16 further comprising a feedback circuit to the processor, wherein the charge level is continually adjusted based on the feedback provided by the feedback circuit.

20. The battery service system of claim 15, wherein the memory is configured to store history information.

21. The battery service system of claim 15 wherein the memory comprises non-volatile memory.

22. The battery service system of claim 21 wherein the memory comprises FLASH memory.

23. The battery service system of claim 15 wherein the display comprises an LCD display.

24. The battery service system of claim 23 wherein the display further comprises an LED indicator.

25. A battery service system comprising:

a processor configured to receive signals from connectors coupled to a battery and to execute control codes;

an input device coupled to the processor;

a display coupled to the processor; and

a memory device coupled to the processor for storing system data and a history of the service,

wherein the control codes, when executed by the processor, control the battery service system to:

abort a service in response to an indication of an improper connection to the battery, and

reinstate the service in response to an indication of a proper connection to the battery.

26. The battery service system of claim 25, wherein the history includes data related to an aborted service.

27. The battery service system of claim 25, wherein the memory comprises non-volatile memory.

28. The battery service system of claim 27, wherein the memory comprises FLASH memory.

29. The battery service system of claim 25 further comprising an interface for communicating with other devices.

30. The battery service system of claim 29, wherein the interface is a USB port.

31. The battery service system of claim 29, wherein the interface is a serial port.

32. The battery service system of claim 29, wherein the interface is an IEEE-1394 port.

33. The battery service system of claim 29, wherein the interface is wireless.

34. The battery service system of claim 25, wherein the display comprises an LCD display.

35. The battery service system of claim 34, wherein the display further comprises an LED indicator.

36. A system comprising:

a processor configured to receive signals from connectors coupled to a battery;

an input device coupled to the processor;

a display coupled to the processor; and

a memory device coupled to the processor for storing data and control codes,

wherein the control codes, when executed by the processor, control the system to perform a battery test, a battery charge service, an alternator test, and a starter test.

37. The system of claim 36, wherein the processor executes the control codes to perform the starter test, the alternator test, and the battery test in a sequence.

38. The system of claim 36, wherein the processor is configured to display prompts to a user and receive inputs from the user during one or more of the battery test, alternator test, and starter test.

39. The system of claim 36, wherein the processor is configured to receive an abort command from a user during one or more of the battery test, alternator test, and starter test.

40. The system of claim 39, wherein the processor is configured to store data in the memory regarding the aborted test.

41. The system of claim 36, wherein the memory comprises non-volatile memory.

42. The system of claim 41, wherein the memory comprises FLASH memory.

43. The system of claim 36 further comprising an interface for communicating with other devices.

44. The system of claim 43, wherein the interface is a USB port.

45. The system of claim 43, wherein the interface is a serial port.

46. The system of claim 43, wherein the interface is an IEEE-1394 port.

47. The system of claim 43, wherein the interface is wireless.

48. The system of claim 36, wherein the display comprises an LCD display.

49. The system of claim 48, wherein the display further comprises an LED indicator.

50. A system comprising:

a processor configured to receive signals from connectors coupled to a battery;

an input device coupled to the processor;

a display coupled to the processor; and

a memory coupled to the processor configured to store service process status,

wherein, under control of the processor, the system is capable of

determining whether the battery is properly connected and

of performing a battery test,

a battery charge service, and

at least one of an alternator test and a starter test.

51. The system of claim 50, wherein the memory comprises non-volatile memory.

52. The system of claim 51, wherein the memory comprises FLASH memory.

53. The system of claim 50, wherein the display comprises an LCD display.

54. The system of claim 53, wherein the display further comprises an LED indicator.

55. The system of claim 50, wherein the battery charge service comprises one of automatic charging, manual charging, trickle charging, or crank assist charging.

56. The system of claim 50, wherein the battery charge service comprises two or more of automatic charging, manual charging, trickle charging, and crank assist charging.

57. The system of claim 50, wherein the battery charge service comprises three or more of automatic charging, manual charging, trickle charging, and crank assist charging.

58. The system of claim 50, wherein the battery charge service comprises automatic charging, manual charging, trickle charging, and crank assist charging.

59. The system of claim 50 further comprising a pulse width modulator controller coupled to the processor for use in the battery charge service.

60. The system of claim 50, wherein the battery test service comprises an impedance test and a load test.

61. The system of claim 50, wherein the alternator service test comprises the processor controlling the display to display prompts to a user.

62. A system comprising:

a processor capable of receiving signals from connectors coupled to a battery;

an input device coupled to the processor;

a display coupled to the processor;

a memory coupled to the processor; and

a pulse width modulation controller coupled to the processor for use in charging the battery,

wherein, under control of the processor, the system is capable of:

(a) receiving battery information via the input device;

(b) charging the battery via the connectors;

(c) measuring a battery charge status via the connectors; and

(d) displaying the battery charge status on the display.

63. The system of claim 62, wherein, under control of the processor, the system is further capable of charging the battery without user intervention.

64. The system of claim 62, wherein, under control of the processor, the system is further capable of charging the battery according to a target battery voltage and thereafter automatically reducing a voltage output to the battery.

65. The system of claim 63, wherein, under control of the processor, charging the battery without user intervention comprises charging the battery according to a target battery voltage and thereafter automatically reducing a voltage output to the battery.

66. The system of claim 62, wherein, under control of the processor, the system is further capable of charging the battery according to a target battery voltage and trickle charging the battery.

67. The system of claim 62, wherein, under control of the processor, the system is further capable of automatically charging the battery according to a target battery voltage and trickle charging the battery.

68. The system of claim 62, wherein the display comprises an LCD display.

69. The system of claim 68, wherein the display comprises an LED indicator.

70. The system of claim 62, wherein the display comprises an LED indicator.

71. The system of claim 62 wherein the memory comprises non-volatile memory.

72. The system of claim 71, wherein the memory comprises FLASH memory.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.	: 8,131,487 B2
APPLICATION NO.	: 12/651421
DATED	: March 6, 2012
INVENTOR(S)	: Dennis G. Thibedeau et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 1, line 45, after "addition,", insert --the--.

Column 3, line 36, change "is" to --are--.

Column 4, line 48, change "signal" to --signals--.

Column 6, line 30, change "form" to --from--;
line 32, after "connection", insert a --.--;
line 55, change "disengages" to --disengage--; and
line 57, after "results", insert a --:--.

Column 7, line 12, capitalize "charging" (second occurrence);
line 22, change "changing" to --charging--;
line 26, change the "," to a --;--;
line 27, change "too" to --to--; and
line 50, change "1F" to --1E--.

Column 8, line 17, change "E" to --1E--;
line 22, delete "enters"; and
line 34, change "an" to --a--.

Column 9, line 5, delete "in";
line 6, delete "a";
line 47, after "well", insert --as--;
line 55, change "to" to --in--;
line 58, change "to" to --in--; and
line 59, change "200," to --2000,--.

Signed and Sealed this
Twelfth Day of June, 2012

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

CERTIFICATE OF CORRECTION (continued)
U.S. Pat. No. 8,131,487 B2

Column 10, line 5, after "operator", insert --to--;
line 47, change "automobiles" to --automobile's--;
line 60, change "consider" to --considered--;
line 66, after "milliohm", insert --; and--; and
line 67, after "milliohm", insert a --.--.

Column 11, line 59, change "set" to --sets--;
line 60, change "saved" to --saves--; and
line 63, after "such", insert --as--.

Column 12, line 43, after "assist", insert --to--; and
line 65, delete "the service process".

Column 14, line 18, after "as", insert --a--.

Column 15, claim 4, line 3, delete "of".